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Validation of thermal models for photovoltaic cells under hot desert climates

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Abstract

The operating temperature of a solar photovoltaic (PV) cell, strongly affected by ambient conditions, is one of the key factors influencing the cell's conversion efficiency. In modelling PV performance, the choice of thermal model is therefore critical with potential impact on simulation results. Most of the traditional main market areas of PV systems are located in regions with a temperate climate. Consequently, performance modelling tools have also been designed and validated mainly based on measurements made in those regions. However, PV capacity building in locations with characteristically different ambient conditions calls for re-calibration of such tools. The present contribution aims to offer simulation tools better suited to the local conditions for effective PV deployment in areas with a hot desert climate. In this analysis, some widely-used operating cell temperature modelling tools are assessed through cross-validation based on weather, power output and module temperature data collected from a test field installed in Abu Dhabi, the United Arab Emirates. The resulting model providing the best fit with the observations gives an RMSE of 4.8% and a practically negligible bias. While most models perform well on clear days, every model is found to give poor predictions on cloudy days. Finally, a need for a more extensive analysis addressing different weather types and PV materials is identified.

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Keywords: Solar photovoltaic; Operating temperature; Hot desert climate

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Nomenclature

C_m	module heat capacity
DHI	diffuse horizontal irradiance
DNI	direct normal irradiance
E	effective irradiance
GHI	global horizontal irradiance
P_{out}	module power output
q_{conv}	convective heat transfer rate
q_{lw}	long-wave radiant flux
q_{sw}	short-wave radiant flux
R^2	coefficient of determination
rBIAS	relative mean bias error
rRMSE	relative root mean square error
t	time
T_a	ambient air temperature
T_c	cell temperature
T_m	module temperature
v_w	wind speed
β	unknown parameter
η_c	cell conversion efficiency

1. Introduction

The operating temperature of a solar photovoltaic (PV) cell is one of the key factors influencing its conversion efficiency and is strongly affected by ambient conditions. Hence, when modelling PV performance, the choice of an operating cell temperature model can have a great impact on the simulation results. Most of the traditional main market areas of PV systems are located in regions with a temperate climate. Consequently, performance modelling tools have also been designed and validated mainly based on measurements made in those regions. When PV capacity building is considered in site locations, whose conditions differ significantly from the ones on the basis of the tools used, recalibration is required.

This work involves the calibration and validation of operating cell temperature modelling tools based on data collected from a test field installed in Abu Dhabi, the United Arab Emirates (UAE) (24° 26' 23" N, 54° 37' 11" E). Abu Dhabi is located in a hot arid region where solar power has a tremendous and largely untapped potential. This study aims to offer simulation tools better suited to the local conditions and thereby support PV deployment in the region.